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Forest Service

Pacific Northwest Forest and Range Experiment Station

Research Note PNW-372

A Method for Sampling Western Spruce Budworm Pupae

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520

Abstract

Pupal density of western spruce budworm, Choristoneura occidentalis Freeman, can be accurately estimated from 45-cm branch tips. Density on tips was representative of densities on entire branches. Mean pupal densities on branch tips are statistically different from lower, mid, and upper crowns ($p = .07$). Therefore, multi-crown sampling is required to precisely estimate the mean of populations similar to those used in this study.

KEYWORDS: Population sampling, insect surveys, sampling methods, insect populations, western spruce budworm, Choristoneura occidentalis

Introduction

Accurate life tables depend on sampling methods that produce a sequence of accurate population density estimates. Although such methods have been developed for the spruce budworm, Choristoneura fumiferana (Clem.) (Morris 1955), these methods must be validated or adapted before they can be safely used for the western spruce budworm, C. occidentalis Free.

The quiescent pupal stage of the budworms is especially suitable for sampling. A single sample taken at the proper time provides information on pupal and adult sex ratios, adult emergence, and mortality from factors that do not remove the entire pupa.[1]

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[1]Predators removed up to 90 percent of the pupae in the western spruce budworm populations we studied in 1979. Methods for quantifying these losses are described in Campbell, Torgersen, and Beckwith (in review).

In this note we describe methods used to sample budworm population densities at four locations in north-central Washington in 1979. The sampling method was adapted from work done in Oregon (Carolin and Coulter 1972).

Study Area

The study area is in the Okanogan National Forest in north-central Washington. Four 5-hectare plots were established in 1978 to represent a range of stand types and budworm densities. Three of the plots are on the eastern border of the North Cascades; the fourth is in the Okanogan Highlands. The primary tree species are Douglas-fir, Pseudotsuga menziesii (Mirb.) Franco, ponderosa pine, Pinus ponderosa Laws., and western larch, Larix occidentalis Nutt.

Plot 1, Rattlesnake Creek (sec. 2, T. 36 N., R. 18 E.) is located in the bottom of the Methow River Valley at an elevation of 790 m. Stocking is mainly Douglas-fir; a few large, residual ponderosa pine account for approximately 3 percent of the total basal area of 29-m^2 per ha. Plot 2, Robinson Creek (sec. 36, T. 37 N., R. 18 E.) is about 1.6 km ENE of the Rattlesnake Creek plot, and about 60 m lower. The stand is mostly small diameter Douglas-fir. Scattered, large ponderosa pine represent 29 percent of the 34-m^2 basal area per ha. Plot 3, Twisp River (sec. 20, T. 34 N., R. 19 E.) is in the upper reaches of the Twisp River Valley at 934 m. The area was logged in the past, but a number of Douglas-fir were left. A few ponderosa pine represent about 3.5 percent of the 22-m^2 basal area per ha. The budworm outbreak represented by these three plots began about 1974 or 1975. Plot 4, B.S. Place (sec. 33, T. 36 N., R. 24 E.) is located in the Okanogan Highlands at 1160 m. The stand was logged approximately 6 years ago and presently contains 22-m^2 of basal area per ha, composed of 64 percent Douglas-fir and 34 percent western larch, with remainder in ponderosa pine. Here, the budworm population started to increase in 1977.

Inter-tree variation in pupal density is more important than between cluster variation (table 3). This suggests that more trees, rather than more clusters, should be sampled. More accurate estimates of pupal density can be obtained by sampling at least two 45-cm tips from each of the three crown levels of several trees in each cluster. We estimated that for these density ranges at least 10 three-tree clusters should be sampled to estimate means with 15 percent precision. Two tips from each of the three crown levels should constitute a sampling unit. Ten clusters of three trees may be used as a preliminary check of the precision. If precision is acceptable, sampling may be terminated; if not, continue sampling until the desired precision is achieved or a time restriction encountered.

Table 3--Analysis of variance table for pupae per square meter (logarithmic scale), using 45-cm terminal tips from each of three crown levels

	Source	df	Mean square	F-value	p-value
1.	Rattlesnake Creek				
	Cluster	4	0.2333		
	Tree within cluster	10	.6345		
	Crown level	2	.2462	1.3518	0.27
	Error	28	.1821		
2.	Robinson Creek				
	Cluster	4	.2197		
	Tree within cluster	10	.2938		
	Crown level	2	.2239	.7202	.50
	Error	28	.3109		
3.	Twisp River				
	Cluster	4	.5435		
	Tree within cluster	10	.0889		
	Crown level	2	.6987	2.8706	.07
	Error	28	.2434		
4.	B.S. Place				
	Cluster	4	.2694		
	Tree within cluster	10	.5170		
	Crown level	2	.1070	.1676	.85
	Error	28	.6385		

Results and Discussion

The mean population density per 100 buds on midcrown terminal and lateral tips, remainder, and whole branches, and the standard error used to test differences are summarized in table 2a. Means for tips, remainder, and whole branches are not significantly different ($p \doteq 0.5$). This suggests that sampling a combination of 45-cm lateral and terminal tips can provide a good estimate of pupal density throughout the tree.

Analysis of terminal tips from each of the three crown levels are summarized in table 2b, to indicate mean pupal density per square meter of foliage and the standard error for testing differences between crown levels. Pupal densities at the three crown levels differed significantly only at Twisp River. This finding suggests that future sampling should include all three crown levels to determine vertical distribution of pupae.

Table 2a--Mean pupae per 100 shoots classified by sections of a branch from midcrown

Source/Location	Rattlesnake Creek	Robinson Creek	Twisp River	B.S. Place
Tips	0.600	2.200	1.547	8.255
Remainder	.499	2.010	1.730	8.899
Whole branch	.588	2.429	1.697	11.317
Standard error	.182	.638	.777	3.499

Table 2b--Mean pupal density per square meter by crown levels

Source/Location	Rattlesnake Creek	Robinson Creek	Twisp River	B.S. Place
Upper crown	6.427	7.860	0.706	29.375
Midcrown	7.181	8.922	4.996	21.337
Lower crown	3.040	5.643	6.513	33.065
Standard error	4.573	1.912	1.512	6.186

Methods

Pupal sampling was conducted during early to mid-July as soon as virtually all of the insects had pupated. At each location, a 5-hectare plot was laid out in a 10- x 10-m grid. This grid was used to randomly locate five points (cluster points). Within each cluster, the three suitable trees closest to the center were marked for sampling. The mean diameter, height, crown length, and age of these trees are shown in table 1. Samples collected from each tree consisted of one 45-cm terminal tip from the middle of the upper crown, another from the lower crown, and two whole branches from the midcrown. Each whole branch was divided into three segments: the terminal 45-cm tip, all lateral 45-cm tips, and "remainder." This method allowed comparisons within branches and between crown levels. For each sample, we recorded surface area, number of buds, and number of pupae. For analysis, the number of pupae were converted to number of pupae per square meter of foliage and per 100 buds.

Table 1--Mean characteristics of sample trees in north-central Washington

Area	D.b.h. (cm)	Total height (m)	Live crown length (m)	Age
Rattlesnake Creek	20.5	12.5	9.8	55.4
Robinson Creek	13.8	10.5	8.1	47.5
Twisp River	15.0	11.2	8.5	46.5
B.S. Place	18.2	12.3	10.1	41.3

Analysis

Logarithmic transformations of data from all 45-cm terminal tips were analyzed by analysis of variance technique to estimate an error term. This term was then used to test for differences between crown levels. Whole branches from midcrowns were analyzed for differences in pupal densities on terminal tips and lateral tips combined, on the remainder, and on whole branches. A two-stage cluster sampling scheme (Cochran 1977) was used to estimate the variance between trees and between clusters. For subsequent sampling, we also estimated the number of clusters and trees per cluster needed to achieve a specified precision.

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GPO 992-438